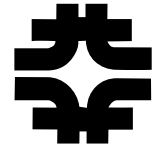


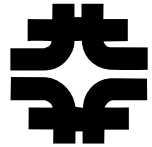
Run II Operations: Current Status and FY05 Plan

Dave McGinnis

Fermilab

March 29, 2005

Plans for FY05

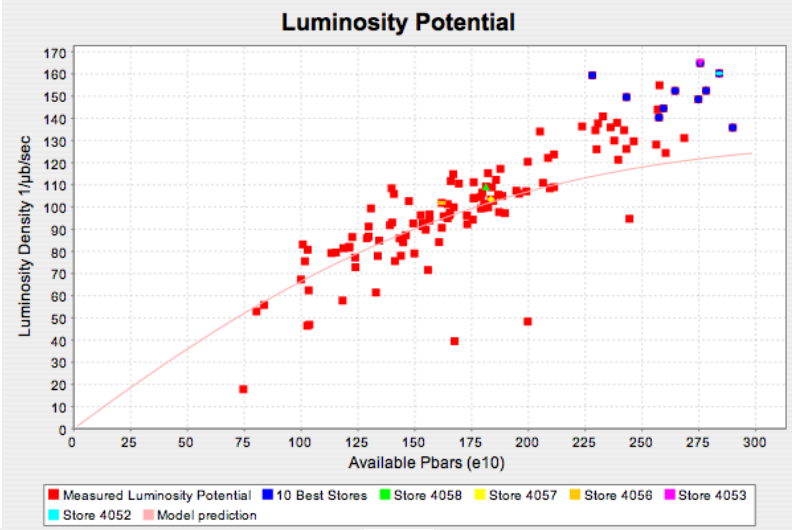


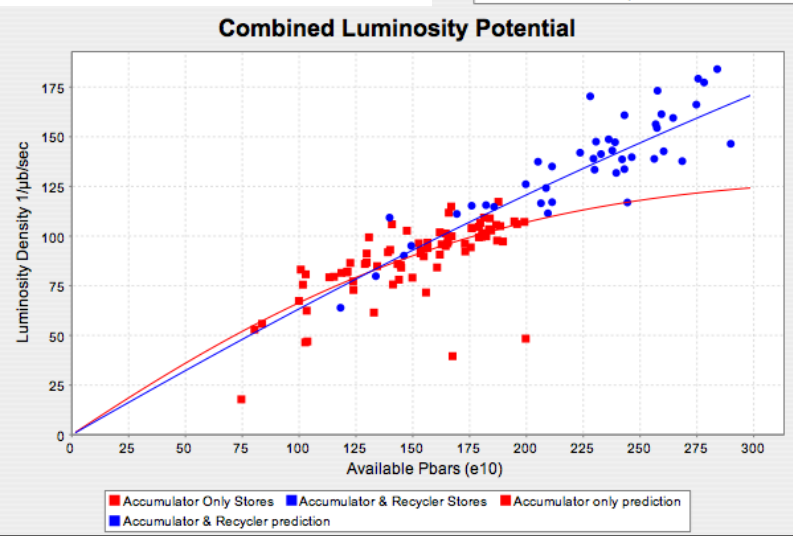
- Install electron cooling in the Recycler in Fall ’04 shutdown
- Run Slip Stacking at $8x10^{12}$ protons/pulse every 2 secs
- Increase the pbar production aperture by 25%
- Stack at small stacks with a rate of $24x10^{10}$ pbars/hr
- Run the complex in Combined Shots operations
  - Assume the gain from Combined Shots operations is “break-even” (pessimistic?)
- Demonstrate electron cooling of antiprotons by the end of FY05
  - 25% Pbar Tax is still in effect
- Integrate $470pb^{-1}$ in 34 weeks (average ~$14pb^{-1}$/week)
- Commission NUMI by early Spring

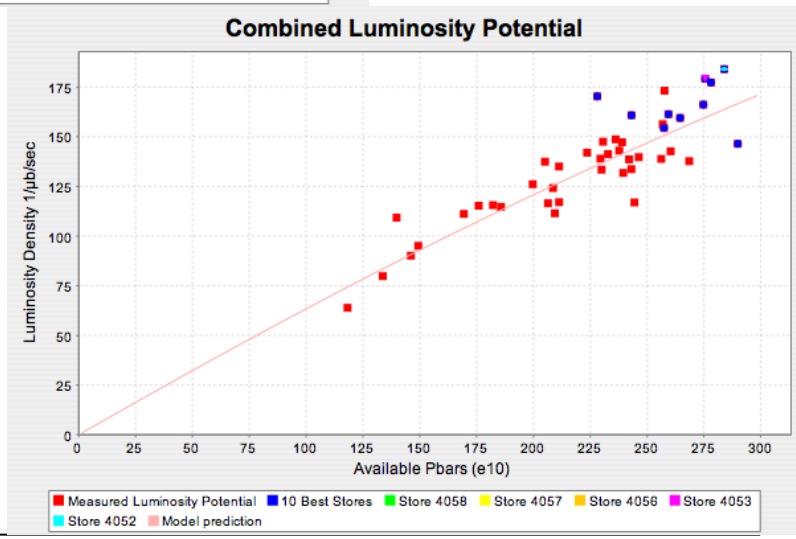
Combined Shots

- Extracting antiprotons from both the Accumulator and the Recycler for the same store i.e.
  - Twelve bunches from the Recycler
  - Twenty four bunches from the Accumulator
- Combined Shot Operation
  - Proposed in February '04 by Brian Chase
  - Initial proposal presented at the April '04 Run II PMG
  - Dual energy ramps in the MI completed and tested by May '04
  - First Attempt 6/13/04
  - Record Luminosity
    - $103 \times 10^{30} cm^{-2} sec^{-1}$ recorded 7/16/04
    - $117 \times 10^{30} cm^{-2} sec^{-1}$ recorded March 2005
  - Routine Operations - January 2005
- Reasons
  - Flexibility in the Run II Upgrade schedule
    - Natural merging of commissioning of electron cooling
  - Push Recycler commissioning progress by plunging it into operations
  - Luminosity enhancement – larger amount of antiprotons for smaller emittances
    - Accumulator stack size limited to <200 mA
      - Stacking Rate
      - Transverse emittance vs Stack Size
- Ratio $I_{Recycler}/I_{Accumulator}$ is governed by:
  - Recycler phase space density (cooling)
  - Recycler transfer time (Rapid transfers)
- Obstacles
  - Stacking Rate
  - Injector Complex 8 GeV energy alignment
  - Longitudinal emittance in both the Accumulator and Recycler
  - Transfer time between Accumulator to Recycler

Stack Size Potential



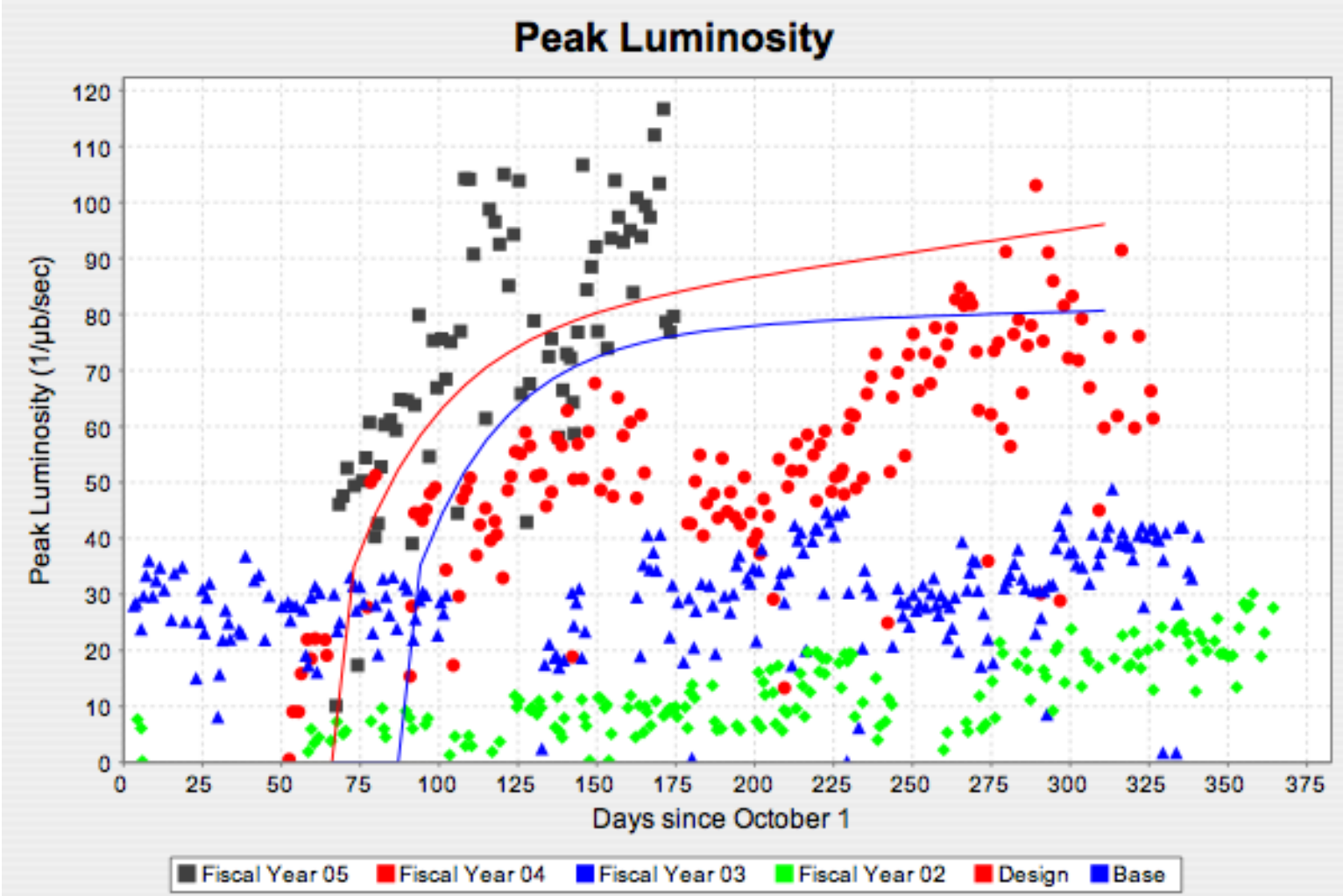




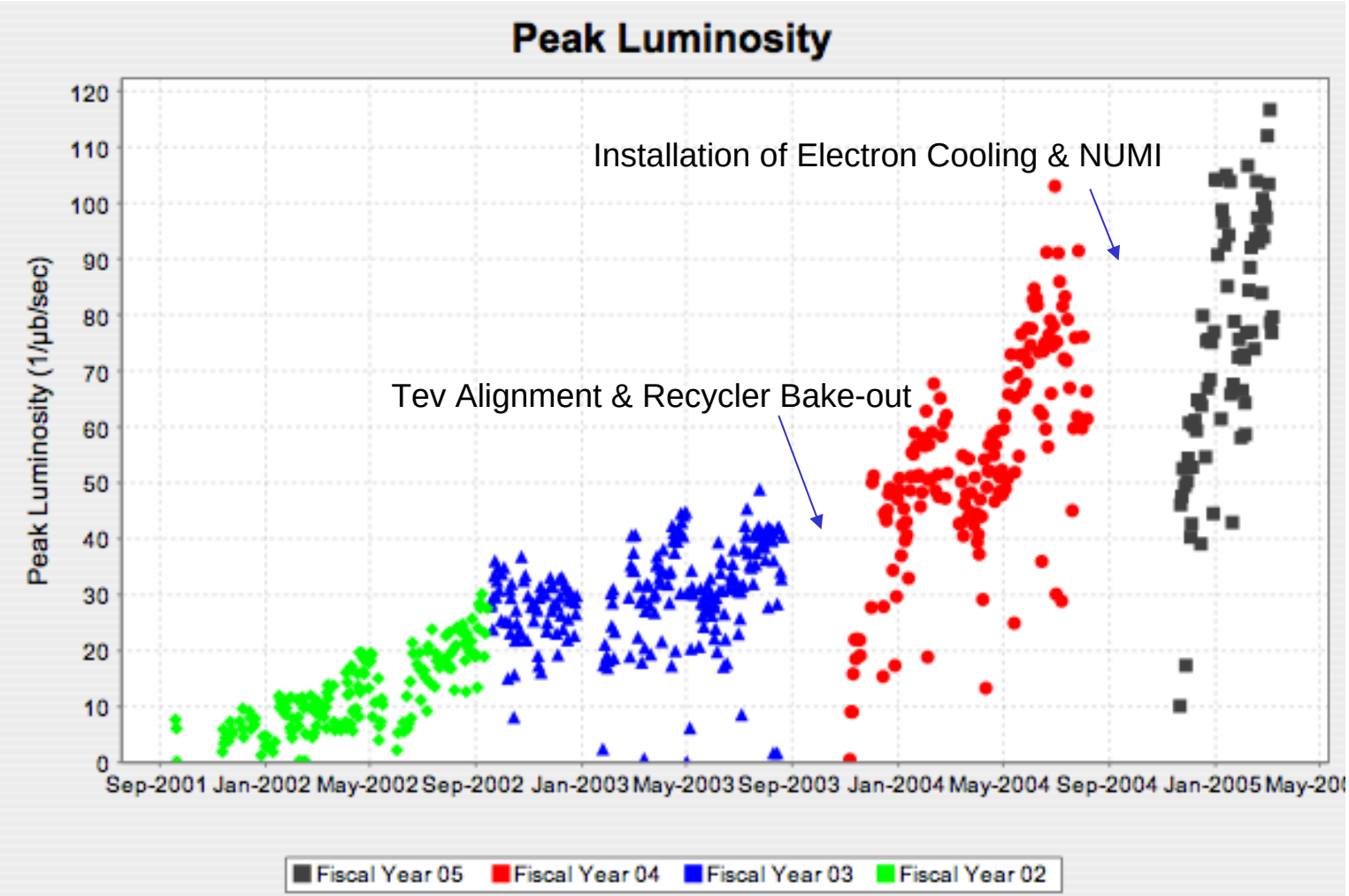
Combined Shots Operations

- After every shot to the Tevatron, stack the Accumulator core back up to 60-90e10.
- Transfer as much of the stack to the Recycler as possible.
  - To keep the longitudinal emittance within reason, the transfers can be done in a number of “mini-transfers” with barrier bucket manipulations in the Recycler between each mini-transfer.
  - If the store is lost before the Accumulator reaches 60-80e10, skip the transfer to the Recycler and stack in the Accumulator until the stack reaches 80-100e10.
    - During this time, the Tevatron is recovering from the lost store followed by studies if time permits.
    - Pbars for the next shot would come only from the Accumulator.
- After the stack is transferred to the Recycler:
  - Re-start stacking to the Accumulator.
  - Continue stacking until the store has stayed in the Tevatron for a total of about 20-25 hours.
    - This should get about 120-150e10 pbars back into the Accumulator.
  - If the store is lost before this, then
    - we will stack until the Accumulator has reached 60-80e10 pbars.
    - During this time, the Tevatron is recovering from the lost store followed by studies if time permits.
- The shot will probably be 2-3 transfers from the Recycler and 7-6 transfers from the Accumulator.

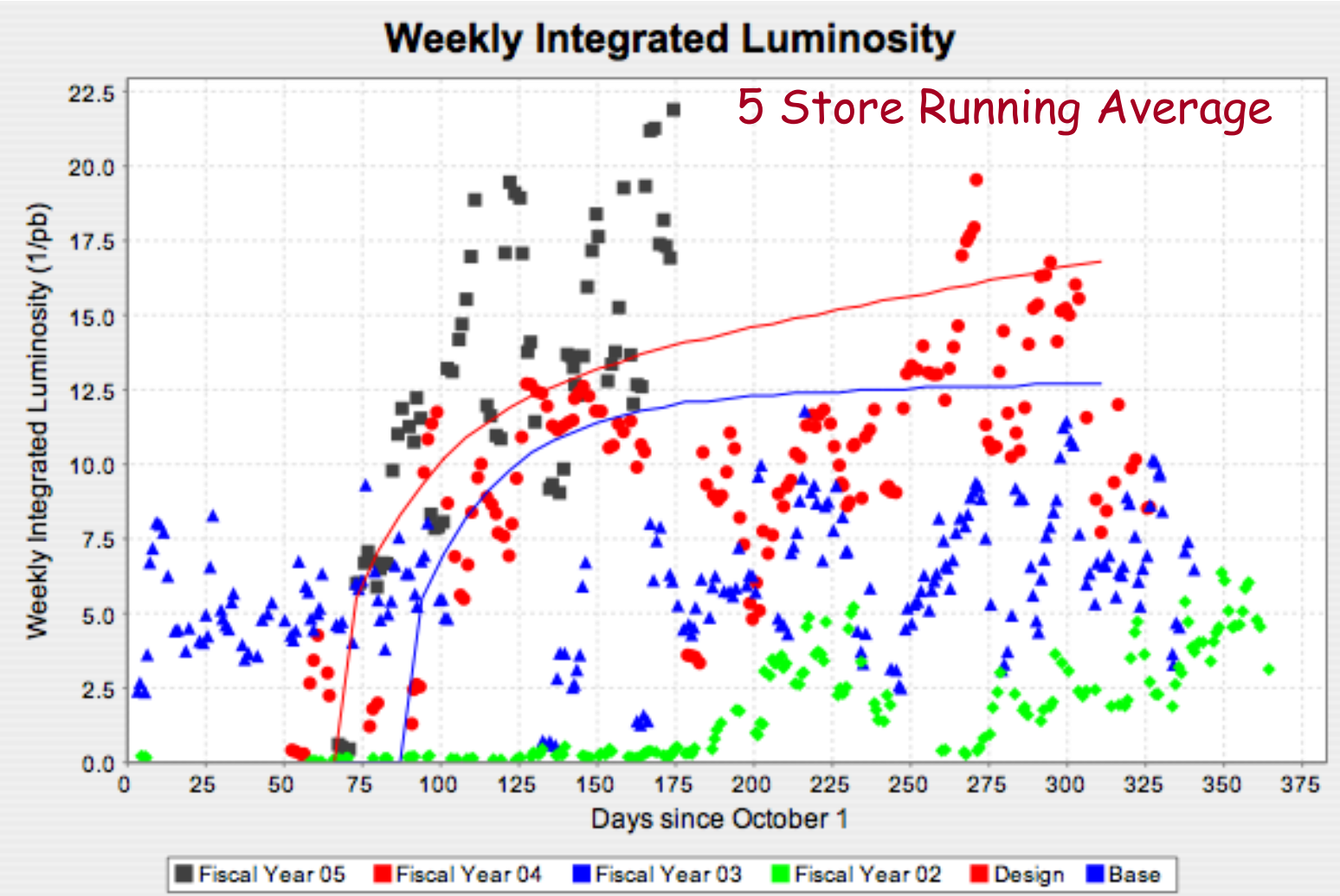
FY05 Peak Luminosity



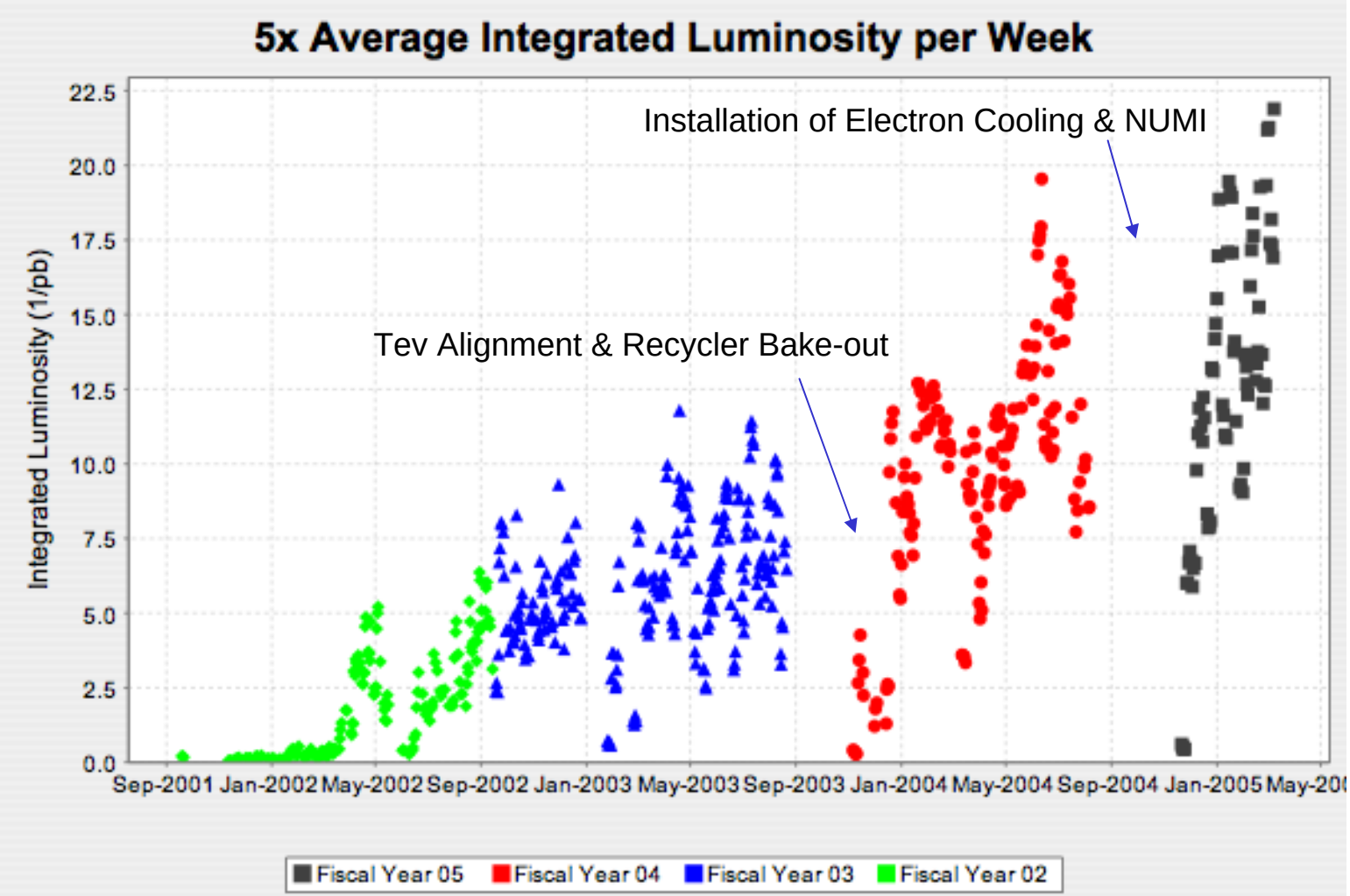
Run II Peak Luminosity



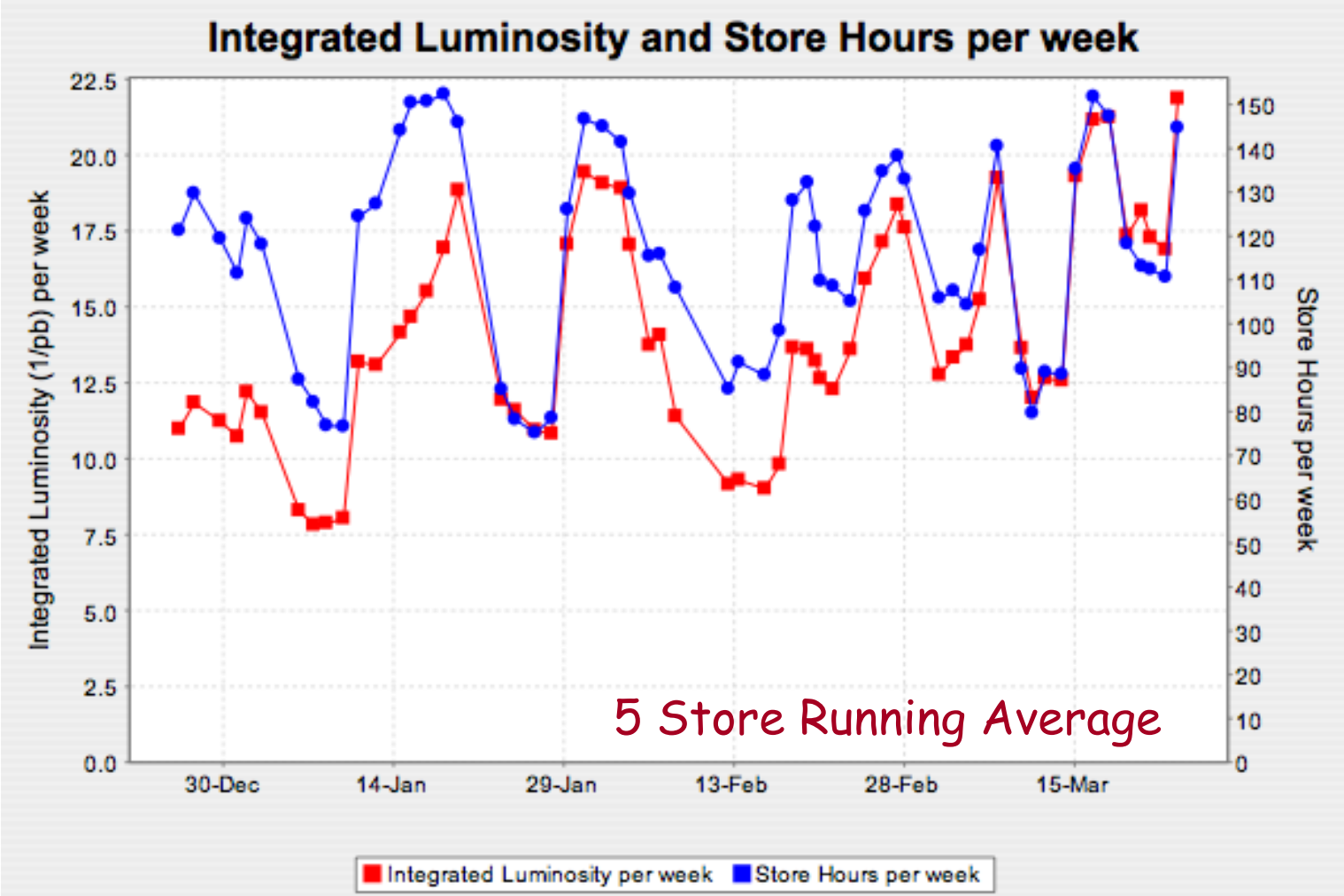
FY05 Weekly Integrated Luminosity



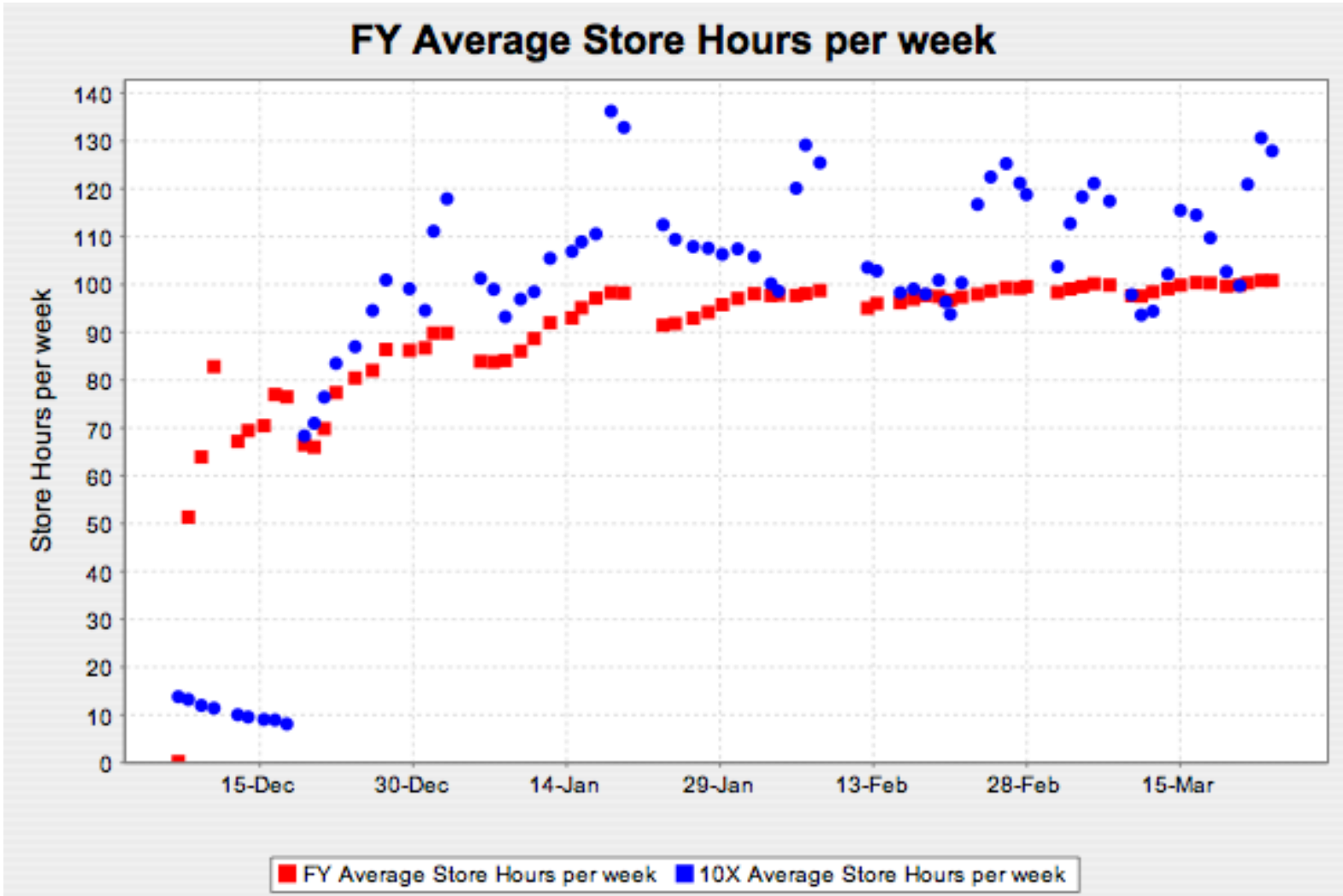
Run II Integrated Luminosity per Week



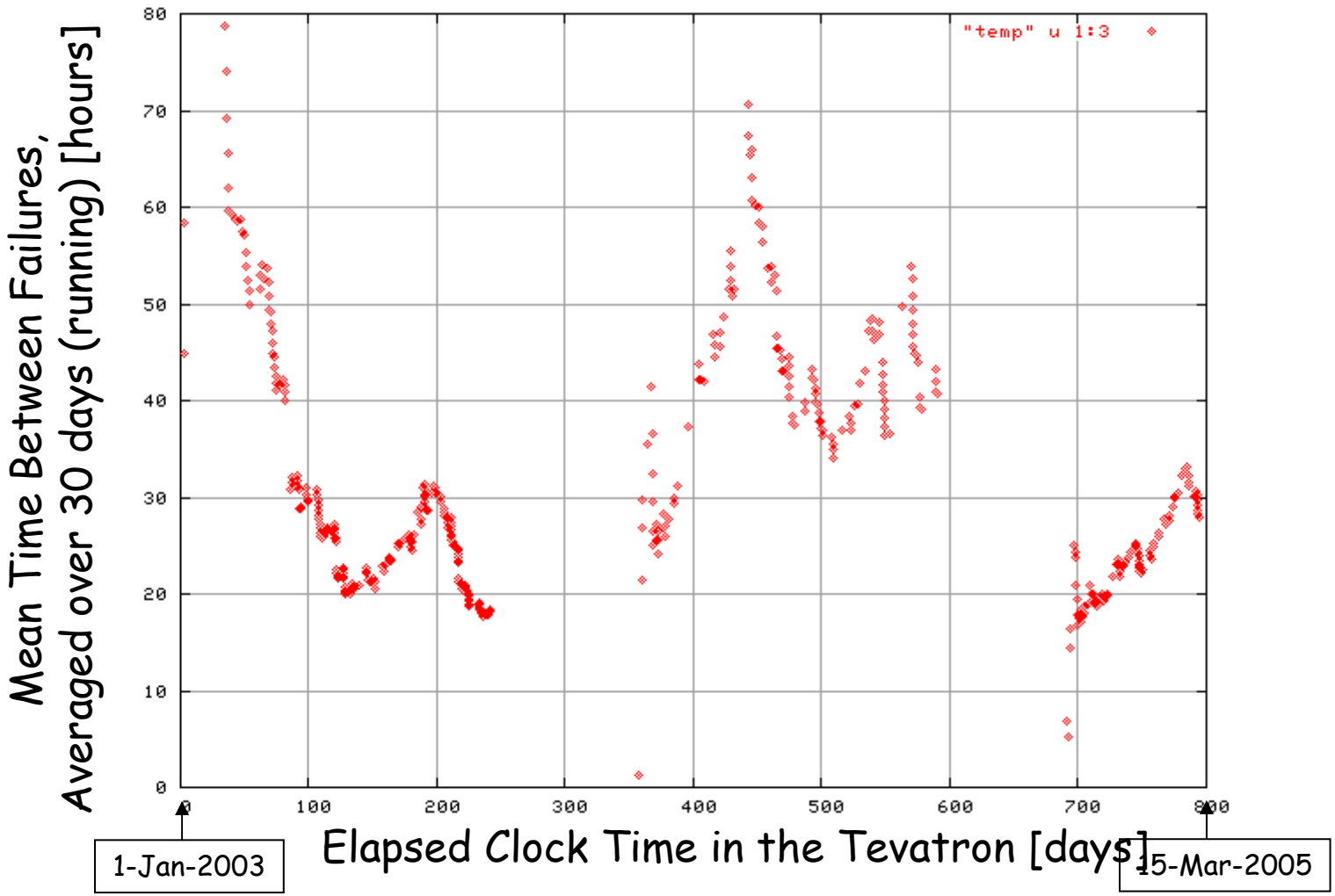
Integrated Luminosity and Store Hours per Week



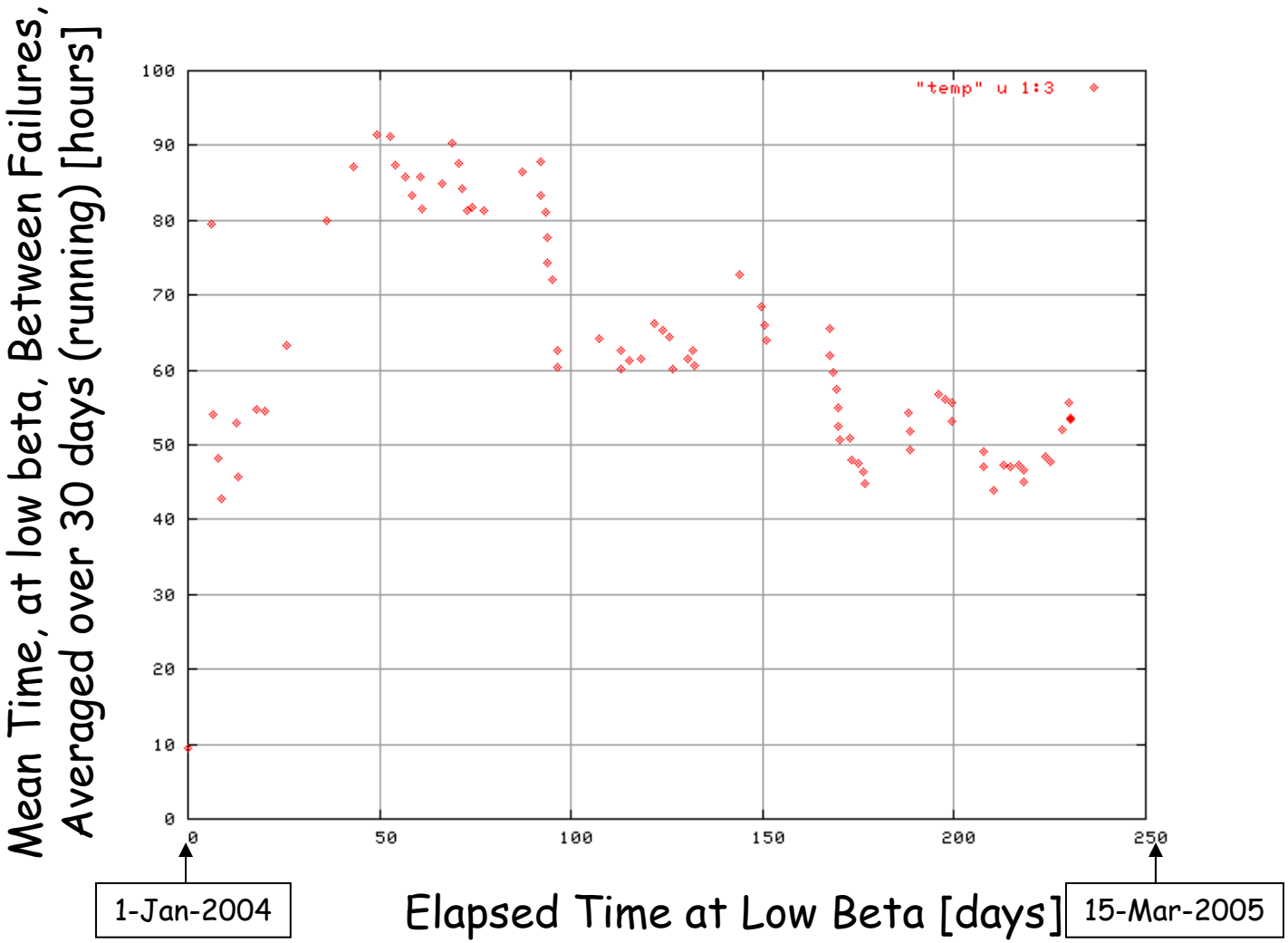
FY05 Average Store Hours per Week



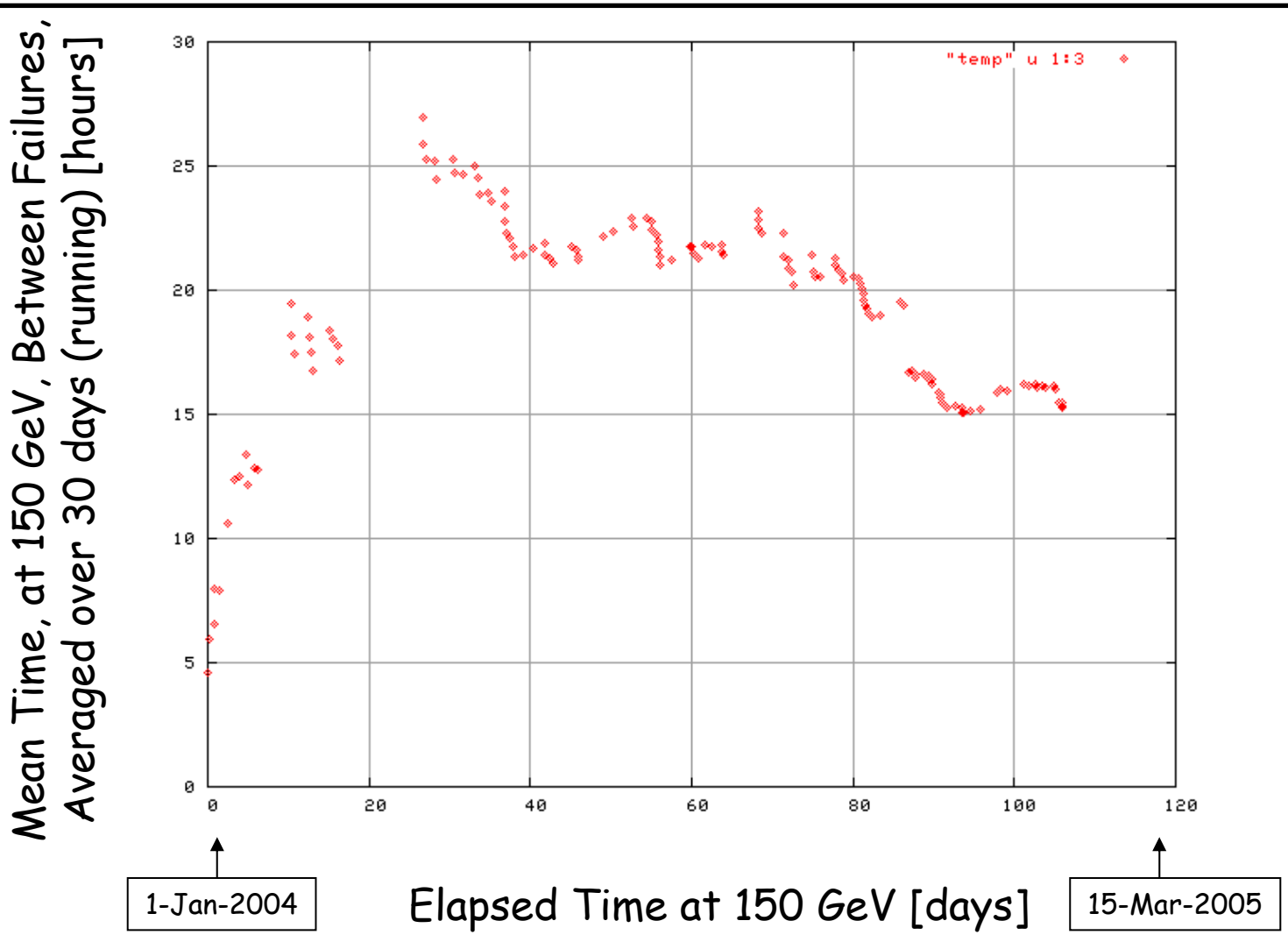
Mean Time Between Failures (MTBF) for the Tevatron



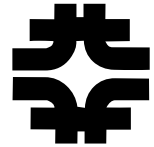
2004-05 Data: MTBF At Low Beta



2004-05 Data: MTBF At 150 GeV

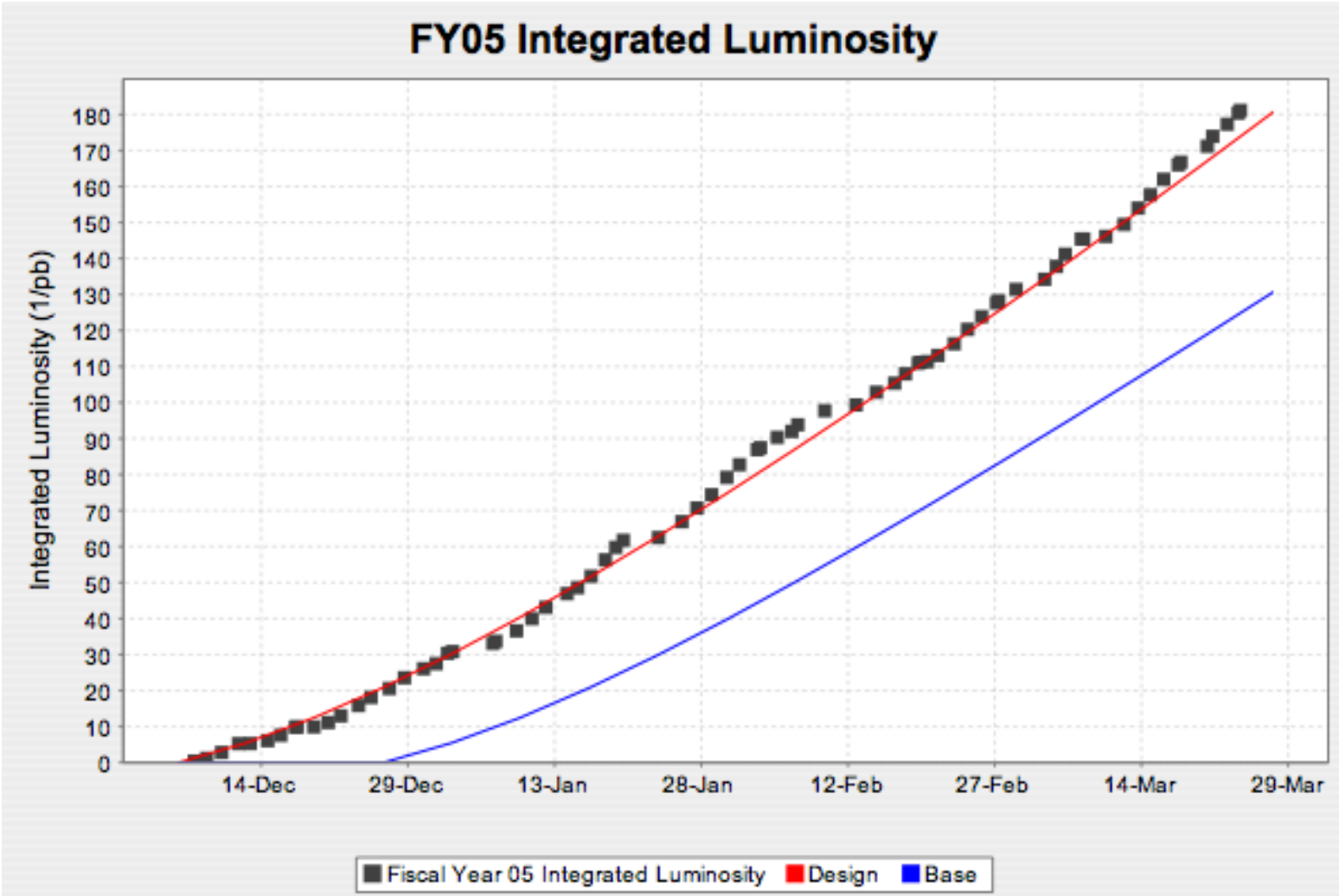


MTBF Conclusions

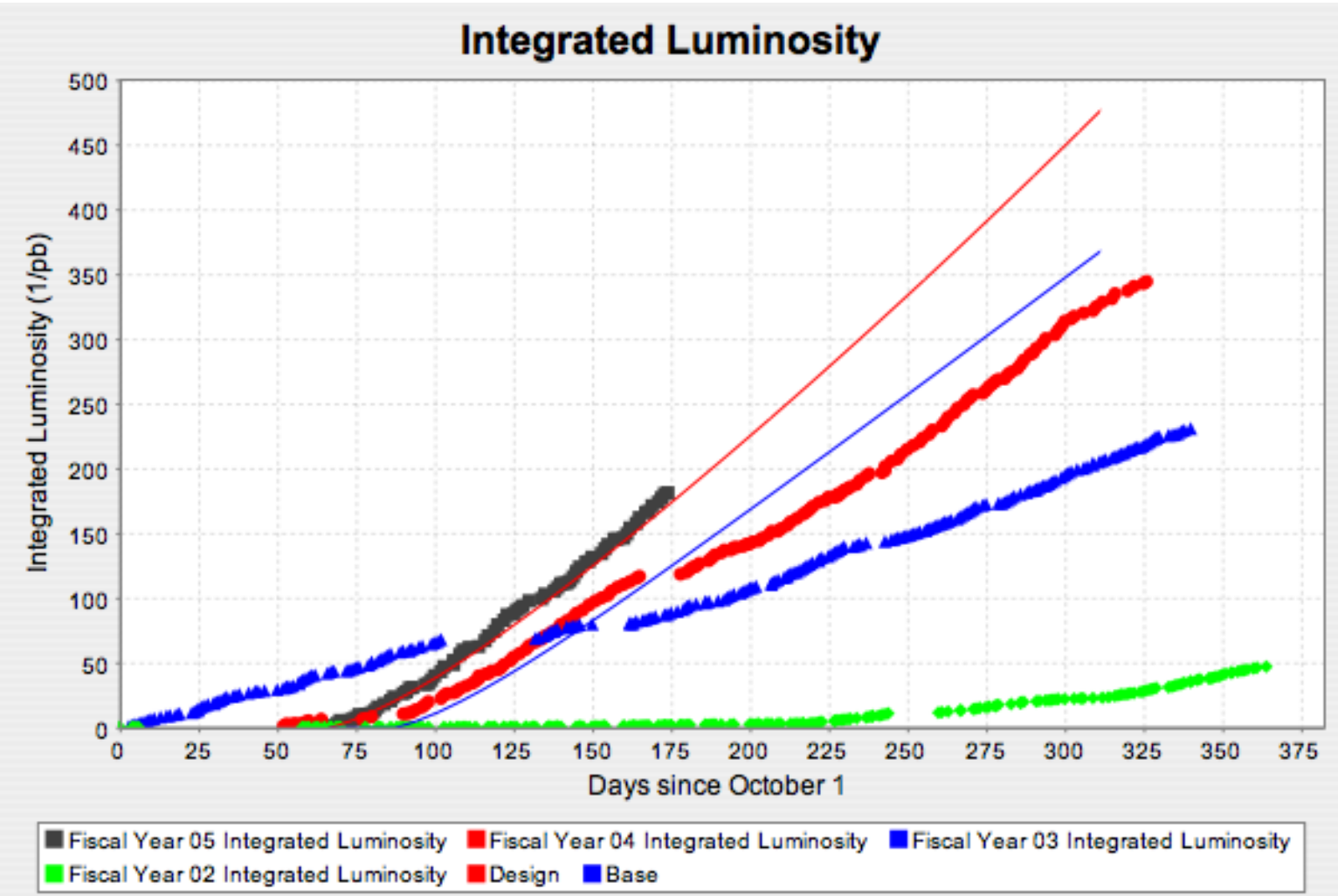


- Tevatron failures are consistent with random failures
  - Although there is some tendency to have a failure shortly after a previous failure
  - An more detailed analysis of the failures can be found in the breakout session for the Tevatron
- The “Low Beta” Tevatron is still quite a bit more reliable than the “150 GeV” Tevatron
  - ~55 hours vs. ~15 hours.
- The MTBF for the Tevatron in 2005 is somewhat worse now than the end of FY04
  - ~30 hours now, vs. ~40 hours then.

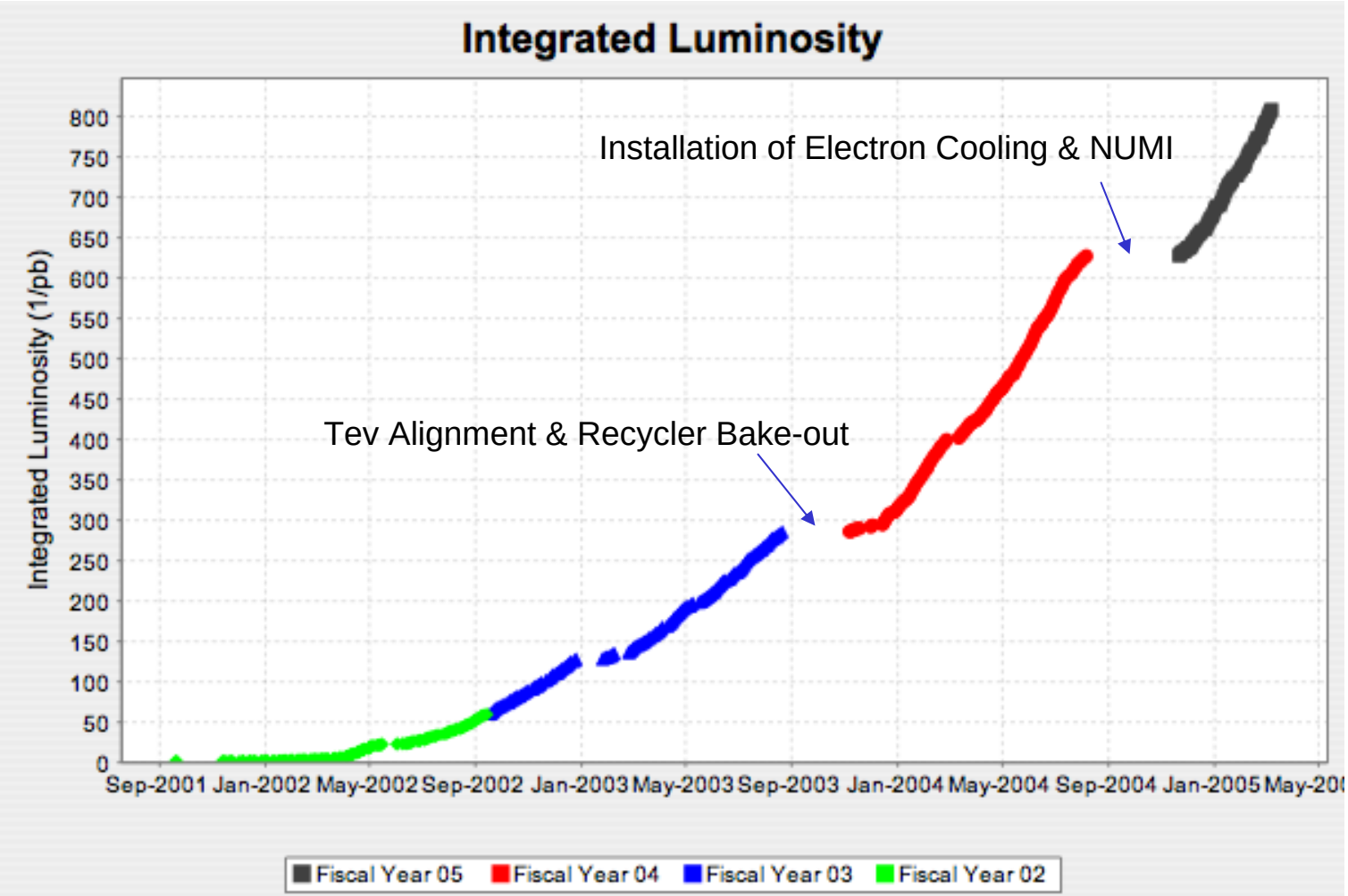
FY05 Integrated Luminosity



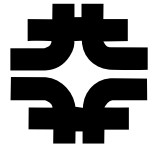
Integrated Luminosity



Run II Integrated Luminosity



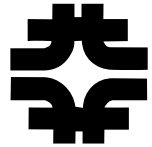
Data Summary Table



Parameter	Last Store	Best Store	Last 10 Stores (Ave)	Best 10 Stores (Ave)	FY Average	Previous FY	FY End Goal (Design)	FY End Goal (Base)	
Luminosity Parameters									
Initial Luminosity (Average)	76.7	116.5	97.9	106.1	74.2	71.1	96.1	80.7	$x10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per Store (Avera	694.1	2746	3184.5	3288	2466.2	2660	3369	3190	nb^{-1}
Luminosity per week (Averaged)	-	-	18.8	-	11.8	11.8	16.8	12.7	pb^{-1}
Store Length	3	11.2	21.6	20.8	21	24.5	20	25	Hours
Store Hours per week	-	-	127.7	-	101	108.3	100	100	Hours
Shot Setup Time	3.6	2.2	2.9	2.6	2.9	2.6	2.6	2.6	Hours
TEVATRON Parameters									
Parameter	Last Store	Best Store	Last 10 Stores (Ave)	Best 10 Stores (Ave)	FY Average	Previous FY	FY End Goal (Design)	FY End Goal (Base)	
Protons per bunch	238.9	237.7	239.7	232.9	222	247.3	260	260	$x10^{9}$
Antiprotons per bunch	32.2	42.3	37.3	41.7	30.9	30.1	42	34	$x10^{9}$
Proton Efficiency to Low Beta	61.3	60.7	65.2	65.4	62.7	72.7	-	-	%
Pbar Transfer efficiency to Low Beta	0	66.4	52.1	68.3	34.7	27.3	76	74	%
HourGlass Factor	0.67	0.67	0.67	0.68	0.68	0.68	0.65	0.65	
Effective Emittance	16.6	14.2	15.1	15.4	15.8	18.1	18.5	17	π-mm-mrad
Antiproton Parameters									
Parameter	Last Store	Best Store	Last 10 Stores (Ave)	Best 10 Stores (Ave)	FY Average	Previous FY	FY End Goal (Design)	FY End Goal (Base)	
Zero Stack Stack Rate	15.6	13.4	14.3	13.8	12.6	12.2	24.5	14	$x10^{10}$/hour
Normalized Zero Stack Stack Rate	2.4	2.3	2.3	2.4	2.2	2.3	3.1	2.3	$x10^{-2}$/hour
Average Stacking Rate	6.5	7.8	8	7	7.2	6.2	10.1	6.6	$x10^{10}$/hour
Stacking Time Line Factor	66.6	79.3	79.1	72.8	76.7	76.6	75	75	%
Stack Size at Zero Stack Rate	305.8	412.9	375.5	363.8	389.7	332.6	300	300	$x10^{10}$
Protons on Target	6.2	5.9	6.1	5.9	5.6	5.2	8	6.2	$x10^{12}$
Start Stack	183.8	275.9	235.6	265.8	183.4	170.7	216	181	$x10^{10}$
End Stack	13.2	46.9	36.3	42.6	20.6	15.8	15	15	$x10^{10}$
Unstacked Pbars	170.6	229	199.3	223.2	162.8	154.9	201	166	$x10^{10}$

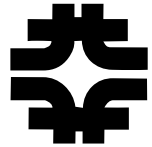
More Info at: http://www-bdnew.fnal.gov/pbar/AEMPlots/today/DataSummaryTables.html

Run II FY05 Accomplishments



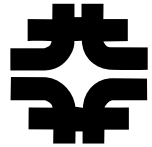
- Routine running of Combined Shots
  - Record luminosity of $117.3 \times 10^{30} cm^{-2} sec^{-1}$
  - Recycler is now operational
  - Potential for fast average stacking
- Routine running of slip-stacking
  - Averaging over 6.5×10^{12} protons on target
  - Have achieved stack rates of over 16.2×10^{10} pbars per hour
- IP Move at CDF (again)
- Run II Upgrade Commissioning
  - Electron Cooling
    - Successfully installed
    - Pelletron at full voltage
    - Electron beam transferred into the Recycler
  - Tevatron BPMs
    - ~25% of the system installed
    - Should finish installation by late spring
  - Tevatron Helix – new separators installed and started up with a new helix
  - Debuncher Admittance
    - All moveable quad stands have been installed
    - Admittance has increased by at least 25%
    - Have achieved stack rates of over 16.2×10^{10} pbars per hour

Fixed Target FY05 Accomplishments



- Record throughput for MiniBoone (8.0×10^{16} protons/hour)
- Routine running of Mixed Mode for SY120 with slip-stacking for pbar production
  - A factor of 7 more spill seconds then originally allocated
  - As NUMI takes the place of SY120 on the antiproton stacking cycles, a new long flattop ramp will keep most of the spill-seconds intact.
- NUMI commissioned
  - First beam on Dec. 4, 2004
  - Around the clock operations on March 14, 2005

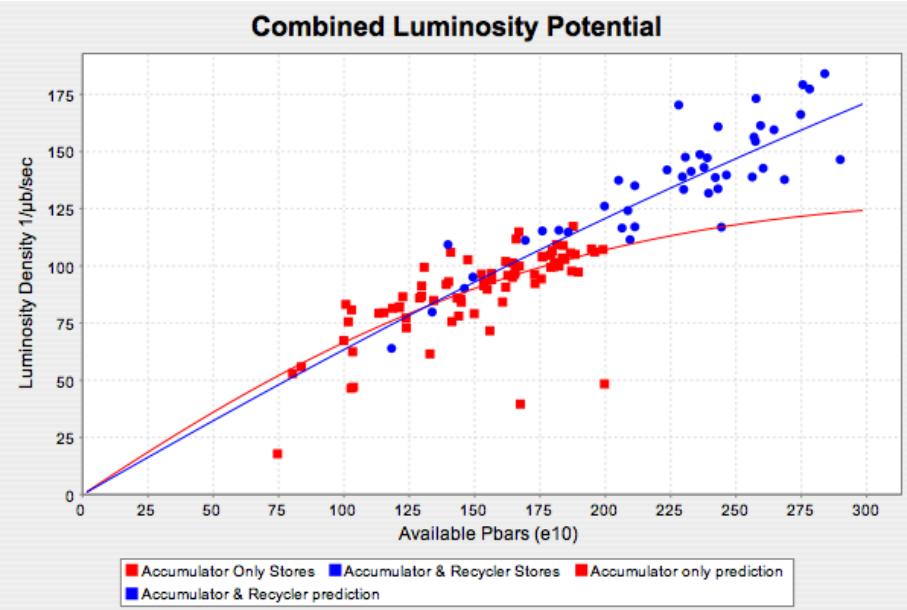
Machine Issues - Machine Studies

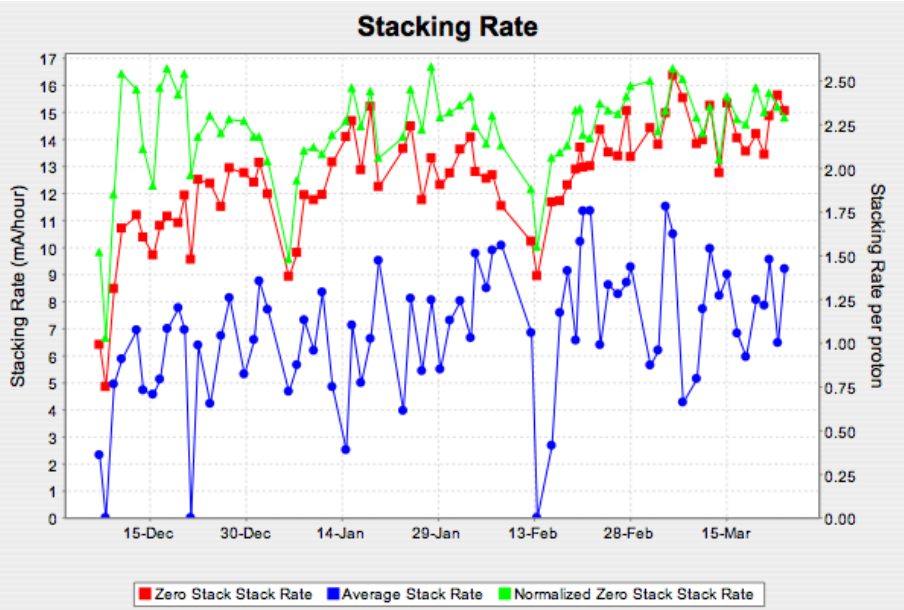


- Over a year ago, we made the strong statement that we are leaving the commissioning phase of Run II behind and entering an operations phase in which we incorporate the Run II Upgrades.
- Although it has taken us awhile to come up with the right way to blend in studies with operations, we have achieved that balance during the second half of FY04.
- The success of this strategy comes from the following points (in order of importance)
  - Accelerator basics are the most important studies. The aperture, orbit, tune, and chromaticity must receive the highest attention.
  - The studies must be focused. That is, when possible, we do one study at a time and finish the studies to a conclusion.
  - Studies are embedded into operations. We follow the rhythm of the machine and use the machine performance as a reality check to the control and benefit of the studies. A natural result of this strategy is that study periods are often short. It is rare for us to schedule more than two study shifts in a row.
  - Injector chain studies have the highest priority (Recycler, MI slip stacking, AP2 aperture, Pbar production). To permit efficient coordination of injector chain studies, we run very long stores.

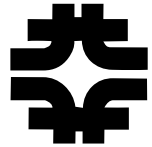
Machine Issues - Stacking Focus

- The success of combined shots operations is directly related to how many antiprotons we can produce.



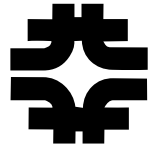


Machine Issues- Stacking Focus



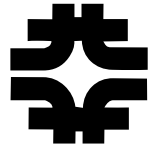
- This pressure to increase the stacking rate has forced us to step up and re-evaluate our study effort for pbar.
  - Pbar study strategy will shift from reverse proton studies to forward pbar studies
    - Will permit more study time
      - Easier to schedule
      - Less disruptive to operations
    - Concentrate on increasing directly the stacking rate
    - Requires better diagnostics
  - Reverse proton studies will be needed but used sparingly
- Increasing the amount of pbar studies will put more pressure on us to run our stores long and to minimize TEV studies in order for us to stay on the red curve.

Machine Issues - Pbar Production



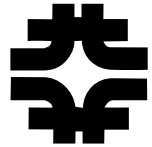
- The momentum spread extracted from the Debuncher into the Stacktail has been decreased by about 35% during FY04.
- The present Stacktail system with the bandwidth as measured should be capable of handling a static flux of 29mA/hr
  - At small stacks, the present Stacktail system can clear the deposition orbit as fast as 1.2 seconds
- In the range of cycle times of interest, the amount of beam reaching the injection orbit of the Accumulator is proportional to how long the transverse cooling is on in the Debuncher.
  - Indicates an aperture problem in the D-A line.

Improvements to the DA Line



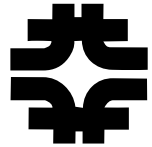
- Laser Tracker survey of the D-A Line
- Developed Lattice Model for survey predictions
- Realignment of the septa
  - Debuncher extraction
  - Accumulator Injection
- Installation of the DEX bump
- Replacement of A:ISEP1
- Developed beam based procedure for aligning beam in transfer line
  - New BPMs and new TBT system
  - New bunching procedure
- Installation of an Accumulator injection 3 bump
- Installation and analysis of Debuncher Gain ramping

New D/A Instrumentation



- Debuncher Beam Bunching Technique (done)
  - Debuncher Intensity measurement – middle of cycle
    - Parasitic – in all the time now
  - D/A Intensity & TBT measurement – end of cycle
    - 50% hit on production – done with one-shots
- Forward Pbar TBT (done)
  - Automatically loads RF curves
  - Code to run local on scope
- Bunched Beam intensity monitors (done)
  - In D/A line
  - In Debuncher
- Forward Pbar BPMs in Debuncher (in progress)
  - Working on position measurment at extraction septum
  - Will convert all BPMs to measure forward pbars using middle of cycle bunching technique
- X-Y plot Software (done)
  - Forward Pbar measurements are noisy
  - Developed ACNET plotting package that shows mean and std. dev. in real time
- Accumulator Injection 3 bump (in commissioning)
- Accumulator Reverse Proton Beam Bunching Technique (done)
- Debuncher Reverse Proton TBT (done)
- DEX BUMP - (in commissioning)

Improvements to the DA Line

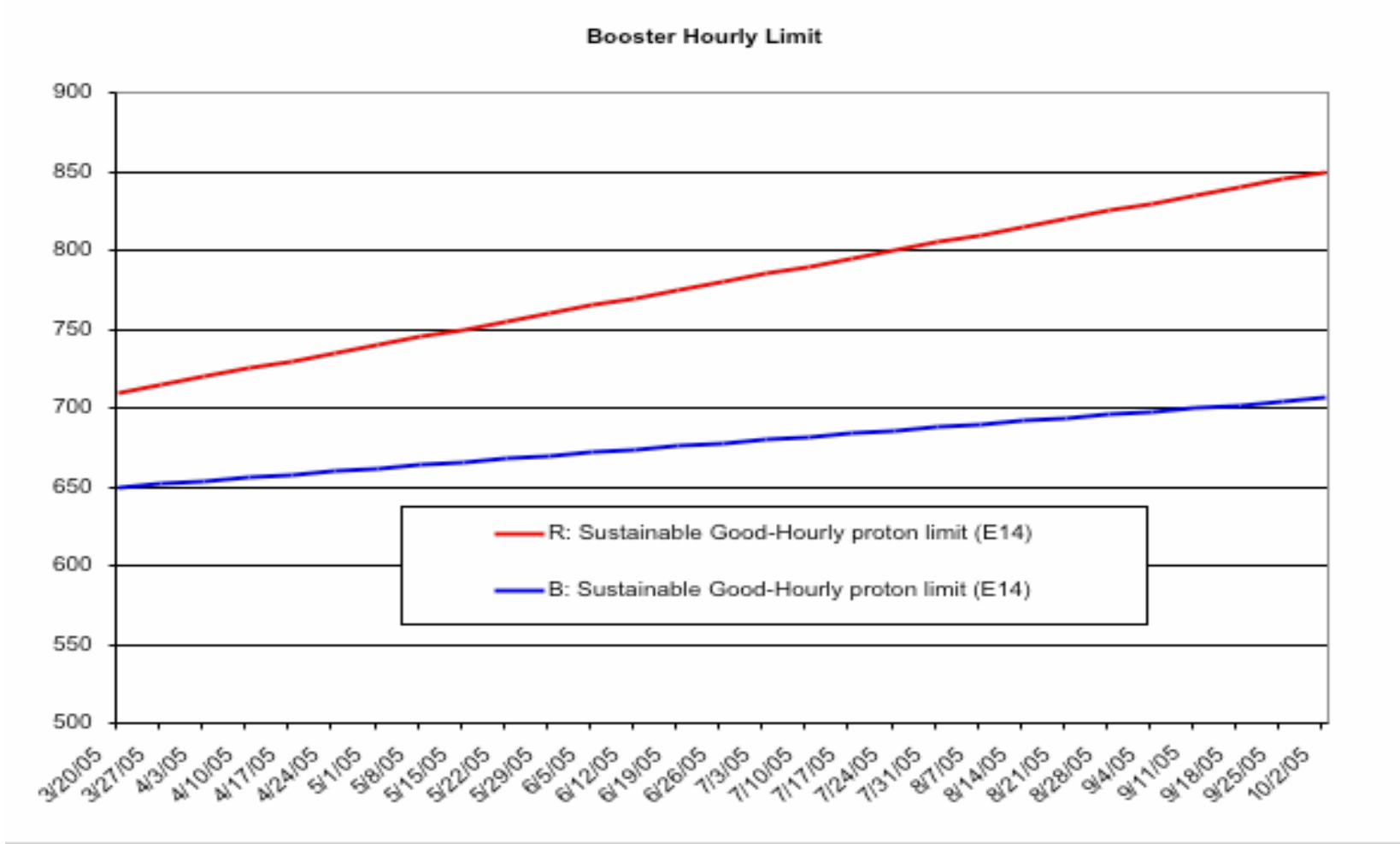


- An initial pass at a beam based alignment of the D/A line has been done
- The ramped Debuncher extraction bump and the Accumulator injection bump are in the process of commissioning
- Once the bump commissioning is complete, the beam based alignment of the D/A line will be finished.
- After the beam based alignment of the D/A line is finished, another cooling time scan of the line will be performed.

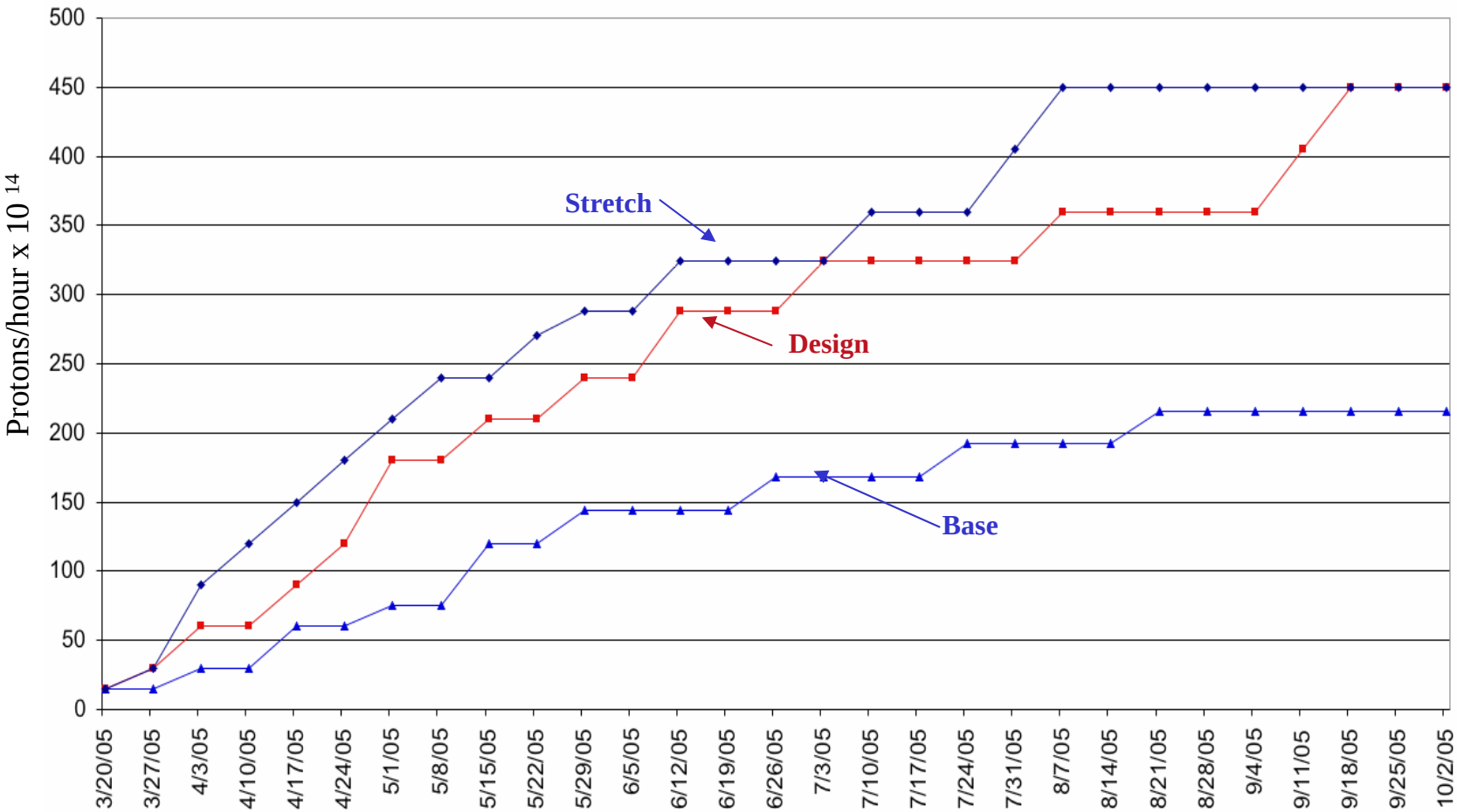
Proton Economics

- The development of design curves for Run II have proved to be very useful management tools for allocating resources.
- With the recent startup of NUMI, we have made an initial pass at design curves for the neutrino program.
- The development of these curves will be discussed in the subsequent talk on the Proton Plan.

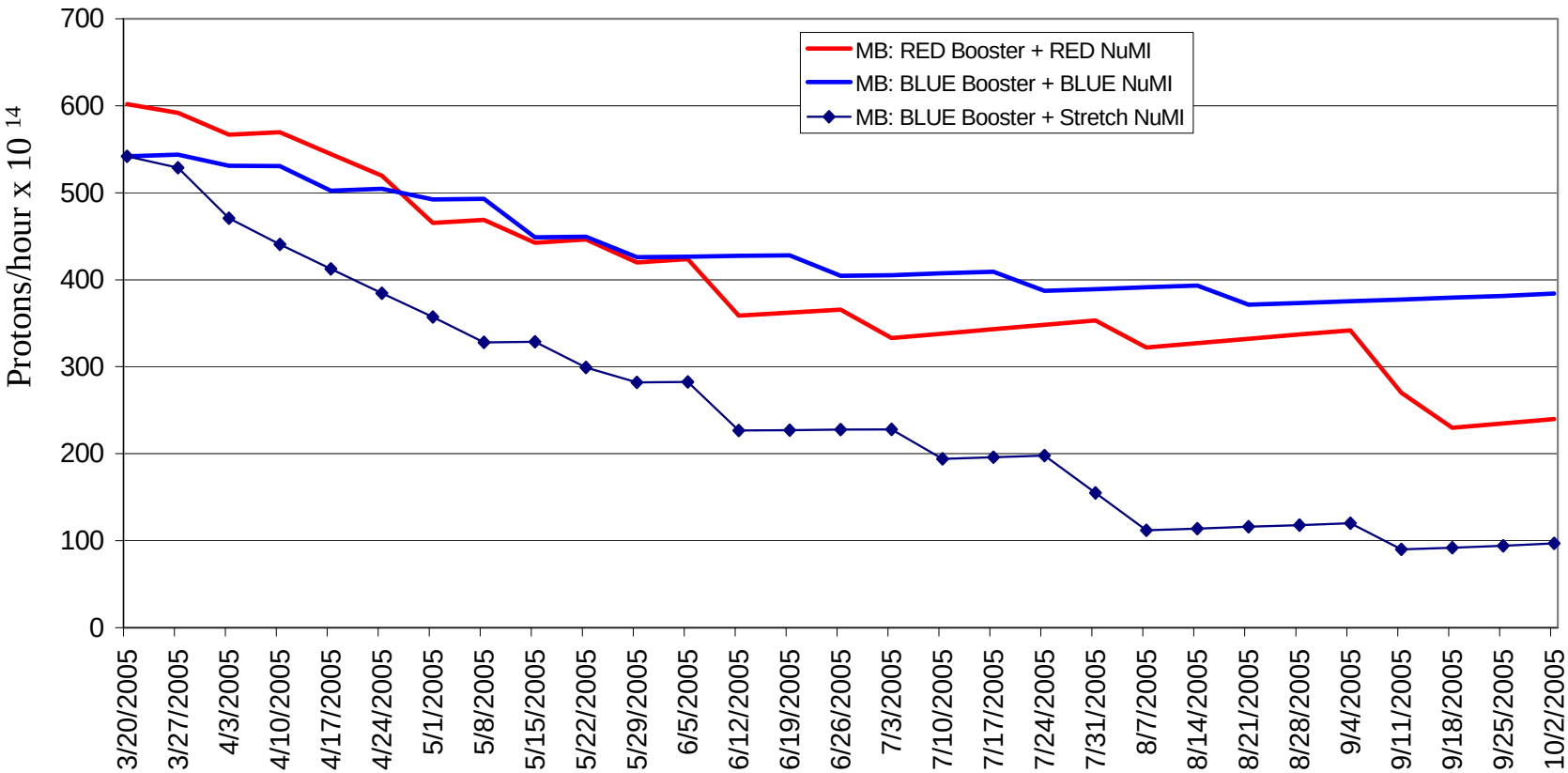
FY05 Booster Projection



FY05 NUMI Projections



FY05 MiniBoone Projections

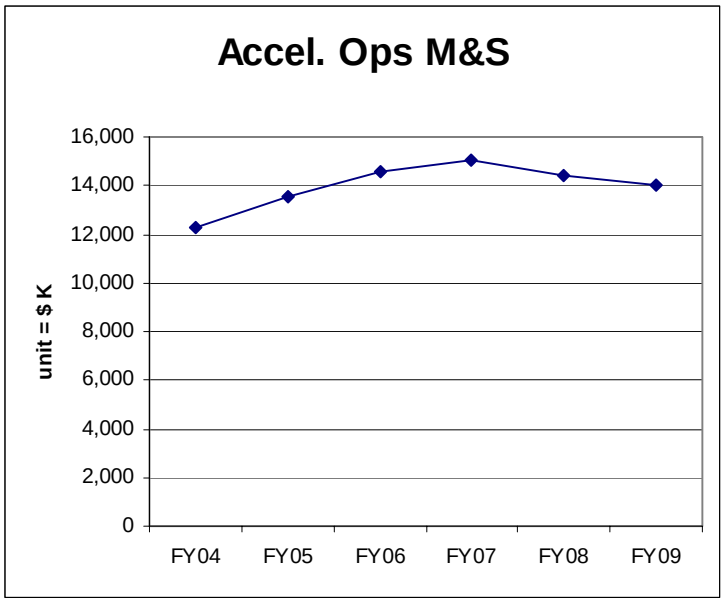


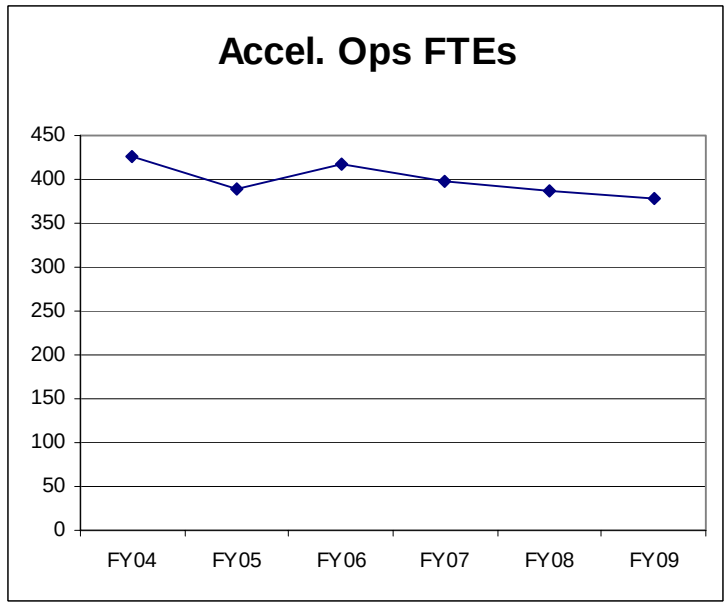
Accelerator Program – all Divisions

ACCELERATOR PROGRAM	FY04	FY05	FY06 PBR	FY07 FLAT	FY08 FLAT	FY09 FLAT
MATERIALS & SERVICES $ K						
ACCELERATOR M&O	12,278	13,469	14,132	14,853	14,181	13,819
ACCELERATOR UPGRADES - R2LU	12,444	7,547	955	0	0	0
ACCELERATOR UPGRADES - OTHER	31	76	406	206	212	219
PROTON PLAN	0	3,854	5,917	5,016	5,242	0
EXP INITIATIVES & EXT BEAMS	633	1,174	577	593	611	629
NuMI BEAM LINE	860	1,149	409	417	430	442
OTHER DIRECT SUPPORT	3,044	2,684	2,917	2,795	2,795	2,795
LHC SUPPORT	0	0	0	0	0	0
SUBTOTAL M&S	29,290	29,953	25,313	23,880	23,471	17,904
FULL TIME EQUIVALENTS	FY04	FY05	FY06 PBR	FY07 FLAT	FY08 FLAT	FY09 FLAT
ACCELERATOR M&O	382	359	381	363	352	343
ACCELERATOR UPGRADES - R2LU	93	85	30	13	0	0
ACCELERATOR UPGRADES - OTHER	44	29	37	35	35	34
PROTON PLAN	0	37	19	18	8	0
EXP INITIATIVES & EXT BEAMS	28	31	35	36	36	36
NuMI / MINOS	29	35	25	25	25	25
OTHER DIRECT SUPPORT	166	158	148	146	140	135
LHC SUPPORT	2	2	1	1	1	1
SUBTOTAL FTEs	744	735	677	638	596	574

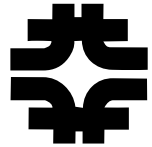
Accelerator Program – all Divisions

Accel. M&O + Upgrades - Other	FY04	FY05	FY06	FY07	FY08	FY09
Materials and Services $ K	12,310	13,545	14,538	15,059	14,394	14,037
Manpower FTEs	426	388	418	418	386	377





Summary



- We will meet our integrated luminosity goal for FY05
- In a period of one year, our peak luminosity has almost doubled
  - We have achieved peak luminosities of $117.3 \times 10^{30} cm^{-2} sec^{-1}$
  - We routinely achieve peak luminosities of $90\text{-}100 \times 10^{30} cm^{-2} sec^{-1}$
- The Recycler is an integral part of operations in the combined shot configuration
- The Run II Upgrades are making very good progress
  - Slip Stacking
  - Electron Cooling
  - Instrumentation – Tevatron, AP2 line, etc..
- We have achieved stacking rates of over 16×10^{10} pbars per hour
  - We have adjusted our study strategy to increase the amount of study time allocated to increasing the stacking rate.
- NUMI has been commissioned
  - A plan exists for how the proton resources are allocated.